Developing a patient safety ontology for knowledge management, data integration, and decision making

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There has been a pressing need for improving patient safety. Sizable amount of Americans do not feel safe about health care, as it is supposed to be [1]. Meanwhile, preventable medical errors that harm patients cost $17.1 billion a year which over-burdened the healthcare system [2]. Although the reasons why errors happen can be complex due to the intricate specification of the system, much attention has been drawn to how patient safety event reporting system can improve the quality and safety of health service over the past decade [3]. An outstanding event reporting system should be able to collect data that link to procedures and factors threaten patient safety in a timely manner. Nevertheless, a great number of reporting systems are suffering low quality of the data, inefficiency and ineffectiveness of data entry [3-5]. One approach aiming at improving the situation is developing a comprehensive and unified ontology for patient safety events. Over the last decade, there has seen a dramatic increase of 600% in the number of citations on ontologies in PubMed/MEDLINE [6], however, the ontology engineering is relatively lagged behind in the field of patient safety. Therefore, the development of ontology towards enhancing patient safety is in an imperative need.

Ontologies or taxonomies developed specifically for use in patient safety system are not new. The Australian Patient Safety Foundation (APSF) originally reported the Australian Incident Monitoring System in 1987, and later in 1993 and 2000, APSF expanded the system twice [7]. A newly developed taxonomy endeavors to categorize major types of human error contributing to medical errors [8]. Other taxonomies or standards such as JACHO patient safety event taxonomy [9], National coordinating council for medication error reporting and prevention (NCC MERP)'s taxonomy of medication errors [10], Neonatal Intensive Care system (NIC) [11], Pediatric Patient Safety taxonomy (PED) [12], Preliminary Taxonomy of medical errors in Family Practice (PTFP) [13], Taxonomy of Nursing Errors (TNE) [14], and Adverse Event Reporting Ontology (AERO) [15] shared insights in specific domains. While these ontologies served primarily as standards of domain specific taxonomies, the rapid increase in medical information calls for a unified knowledgebase with unified language system to be used as a common denominator for sharing and learning across patient safety reporting systems.

In this project, we built a semantic web ontology (Medeon) using W3C open standard Web Ontology Language (OWL) (Fig. 1). The Common Formats (v1.2) developed by the Agency for Healthcare and Research Quality (AHRQ) were employed as the taxonomy where we extracted and encoded semantic knowledge into Medeon. Recognized as a unified standard of reporting patient safety events, the Common Formats are designed to specify and collect event information, which range from general concerns to frequently occurring and serious types of the events. We chose OWL and semantic web technologies because they jointly provide unique advantages for machine understandable semantics and descriptive logic reasoning which allows us to model real-world patient safety data in a computerized system. We borrowed the hierarchical structure in the Common Formats to build the OWL classes and rephrased the narrative data in the Common Formats to construct OWL incidents and objective properties. In order to share the knowledge of the Common Formats with other domain ontologies, Unified Medical Language System (UMLS) was employed to map terminologies between different domains.

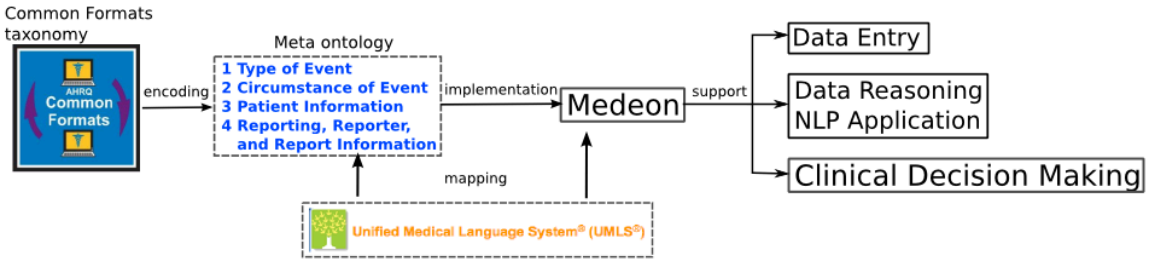

Fig. 1. A general procedure of generating Medeon. Images were adapted from AHRQ Common Formats (https://www.pso.ahrq.gov/common) and US National Library of Medicine. (http://www.nlm.nih.gov/research/umls/)

Our ontology lay out to improve patient safety reporting system in the following aspects. The ontology primarily serves as a knowledgebase to model the taxonomies broadly used for patient safety events. With this knowledgebase, semantic data can be retrieved and reasoned through descriptive logic rules and applied to text mining methods. Secondly, the use of UMLS provides a framework to encode and exchange data between our ontology and other semantic data repositories. In the end, our ontology holds promise in facilitating decision support in clinical research [16]. However, it is most challenging in mapping between discrepant data sources due to the distinction among existing taxonomies in terms of the hierarchical structure and terminologies. The next step will focus on this issue by evaluating the current ontology with event reports.

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Reference

[1] Kohn, L.T., J.M. Corrigan, and M.S. Donaldson, *To Err Is Human:: Building a Safer Health System*. Vol. 627. 2000: National Academies Press.
[2] Van Den Bos, J., et al., *The $17.1 billion problem: the annual cost of measurable medical errors.* Health Affairs, 2011. **30**(4): p. 596-603.
[3] Pronovost, P.J., et al., *Improving the value of patient safety reporting systems.* Advances in patient safety: new directions and alternative approaches, 2008. **1**.
[4] Gong, Y. *Terminology in a voluntary medical incident reporting system: a human-centered perspective*. in *Proceedings of the 1st ACM International Health Informatics Symposium*. 2010. ACM.
[5] Gong, Y., *Data consistency in a voluntary medical incident reporting system.* J Med Syst, 2011. **35**(4): p. 609-15.
[6] Bodenreider, O., *Biomedical ontologies in action: role in knowledge management, data integration and decision support.* Yearbook of medical informatics, 2008: p. 67.
[7] Spigelman, A.D. and J. Swan, *Review of the Australian incident monitoring system.* ANZ journal of surgery, 2005. **75**(8): p. 657-661.
[8] Zhang, J., et al., *A cognitive taxonomy of medical errors.* Journal of biomedical informatics, 2004. **37**(3): p. 193-204.
[9] Chang, A., et al., *The JCAHO patient safety event taxonomy: a standardized terminology and classification schema for near misses and adverse events.* International Journal for Quality in Health Care, 2005. **17**(2): p. 95-105.
[10] Brixey, J., T.R. Johnson, and J. Zhang. *Evaluating a medical error taxonomy*. in *Proceedings of the AMIA Symposium*. 2002. American Medical Informatics Association.
[11] Suresh, G., et al., *Voluntary anonymous reporting of medical errors for neonatal intensive care.* Pediatrics, 2004. **113**(6): p. 1609-1618.
[12] Woods, D.M., et al., *Anatomy of a patient safety event: a pediatric patient safety taxonomy.* Quality and Safety in Health Care, 2005. **14**(6): p. 422-427.
[13] Dovey, S.M., et al., *A preliminary taxonomy of medical errors in family practice.* Quality and Safety in Health Care, 2002. **11**(3): p. 233-238.
[14] Woods, A. and S. Doan-Johnson, *Toward a Taxonomy of Nursing Practice Errors.* Nursing Management, 2002. **33**(10): p. 45-48.
[15] Courtot, M., R.R. Brinkman, and A. Ruttenberg, *The Logic of Surveillance Guidelines: An Analysis of Vaccine Adverse Event Reports from an Ontological Perspective.* PloS one, 2014. **9**(3): p. e92632.
[16] Huff, S.M. and R.A. Greenes, *Ontologies, vocabularies, and data models.* Clinical Decision Support: The Road Ahead, 2007: p. 307-421.

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Introduction

- Although the importance of patient safety has been increasingly recognized across the world, the reduction and prevention of safety events are not as good as expected.
- Recently, much attention has been paid to patient safety reporting system which holds promise in improving the situation.
- One roadblock in the system has been the lack of comprehensive taxonomy on patient safety events to support knowledge management, data integration, and decision making.
- To meet this imperative need, we aim at developing a unified semantic web ontology of patient safety events to serve as a general guideline.

General Framework

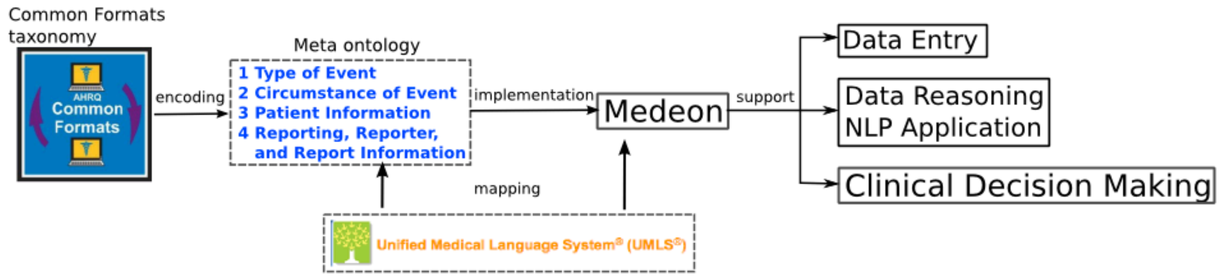

Fig 1.General framework of constructing Medeon.

Mapping Procedure

A

2.0 Circumstances of Event
- 2.1 Date and time of event
  - 2.1.1 Date the event was discovered
  - 2.1.2 Time the event was discovered
- 2.2 Where event occurred or unsafe condition exists
  - 2.2.1 Inpatient general care area (e.g., medical/surgical unit)
  - 2.2.2 Special care area (e.g., ICU, CCU, NICU)
  - 2.2.3 Labor and delivery

B

1. Report Date: ___ ___ / ___ ___ / ___ ___ ___ ___ (MM / DD / YYYY)

2. What is being reported? CHECK ONE:
- a. ☐ **Incident:** A patient safety event that reached the patient, whether or not the patient was harmed.
- b. ☐ **Near Miss:** A patient safety event that did not reach the patient.
- c. ☐ **Unsafe Condition:** Any circumstance that increases the probability of a patient safety event.

3. Event Discovery Date: ___ ___ / ___ ___ / ___ ___ ___ ___ (MM / DD / YYYY)

4. Event Discovery Time: ___ ___ ___ ___ HOURS (H H M M (MILITARY TIME)) ☐ Unknown

Fig 2. An example of the mapping procedure

❖ Step1, we retained the original hierarchical structure in the Common Formats and formed a meta ontology which contains four OWL classes and has a maximal depth of four. Fig 2A is an example of the event description form which summarizes the overall hierarchical structure of the patient safety events in the Common Formats. Fig 2B is an example of Healthcare Event Reporting Form (HERF).

❖ Step 2, we manually rephrased the entities before adding them as OWL classes to the ontology. Part of the entities in the Common Formats were judged as OWL instances, therefore were imported to the ontology as OWL instances. See Fig 3.

❖ Step 3, we are collaborating with domain experts to define and evaluate the OWL object properties since the Common Formats do not provide semantic data in guiding OWL object properties.

❖ Step 4, after the semantic representation was established, we were able to use the ontology to perform tasks such as consistency checking, automatic classification and semantic reasoning

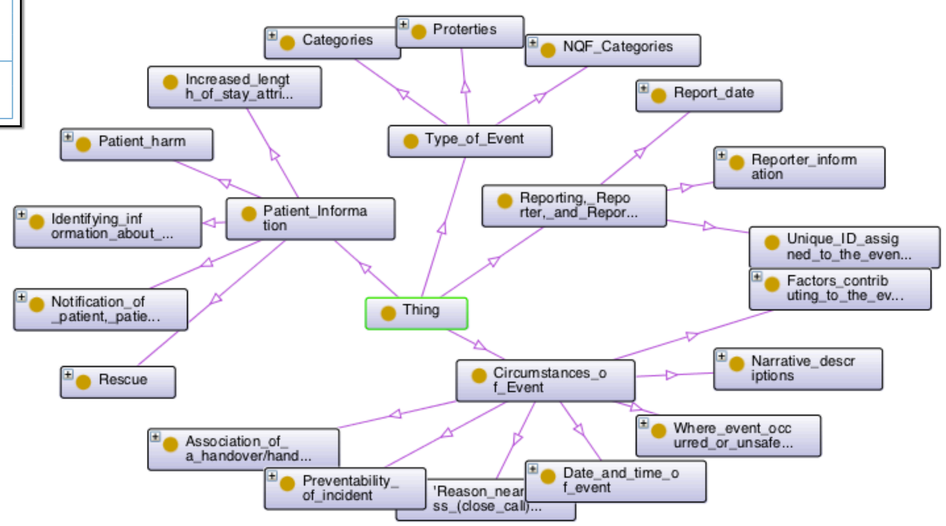

Fig 3 is a screenshot from OntoGraf, a build-in visualization tool in Protégé 4.3.0. The screenshot depicts the top two levels of OWL classes mapped from the Common Formats.

Conclusion and Future Steps

Our ontology layout to improve patient safety reporting system in the following aspects.

- It serves as a knowledgebase to model the taxonomies broadly used for patient safety events.
- With this knowledgebase, semantic data can grow as the knowledge to keep with the development in the real-world.
- Semantic data can be retrieved and reasoned by using descriptive logic rules and applied to text mining methods.
- It holds promise to largely facilitate decision support in clinical research.

Our next step will address,

- To add knowledge from other existing patient safety taxonomies into Medeon,
- To use named entity recognizer and UMLS to label from real-world data and further improve Medeon,
- To perform evaluation using real patient safety reports.

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